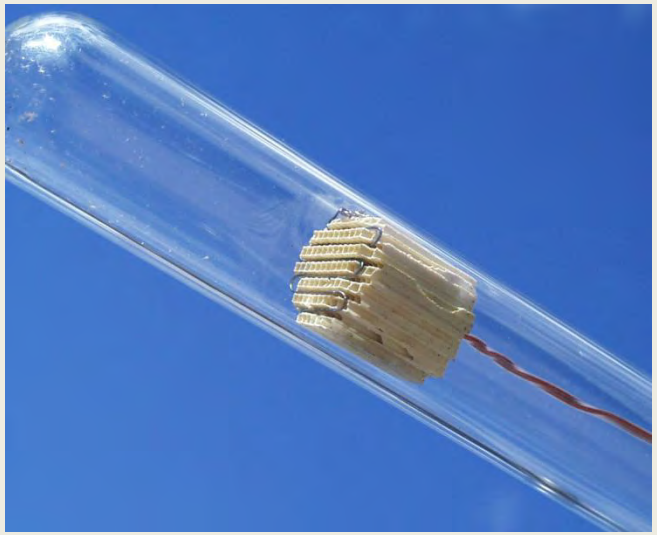

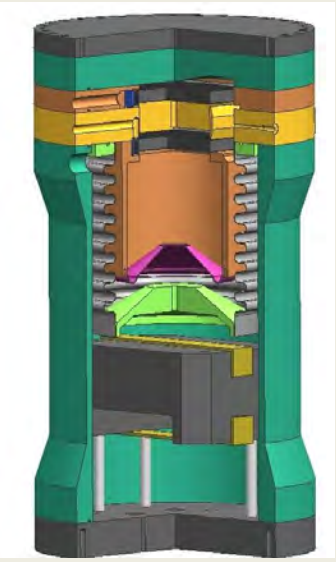

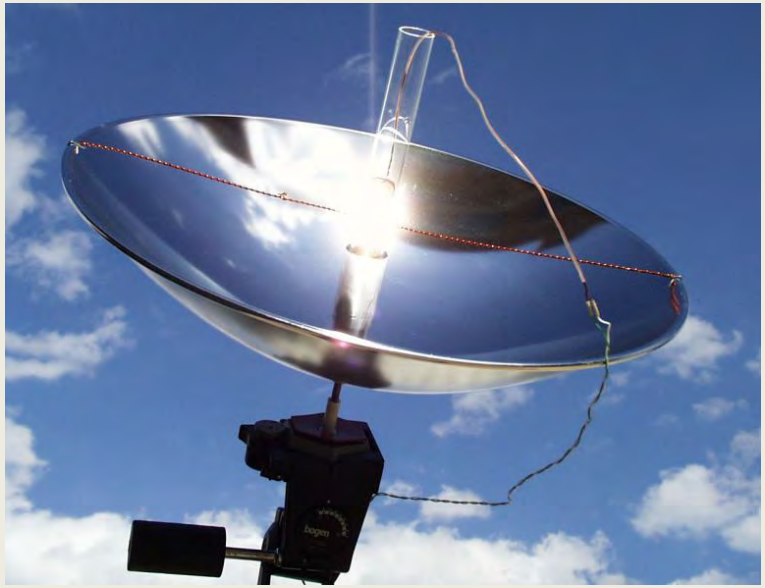

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ASEAN-US Next-Generation Cook Stove Workshop:

Session 4 – Utilizing Stove Heat for Co-Generation

Wednesday Afternoon - 18 Dec 2009

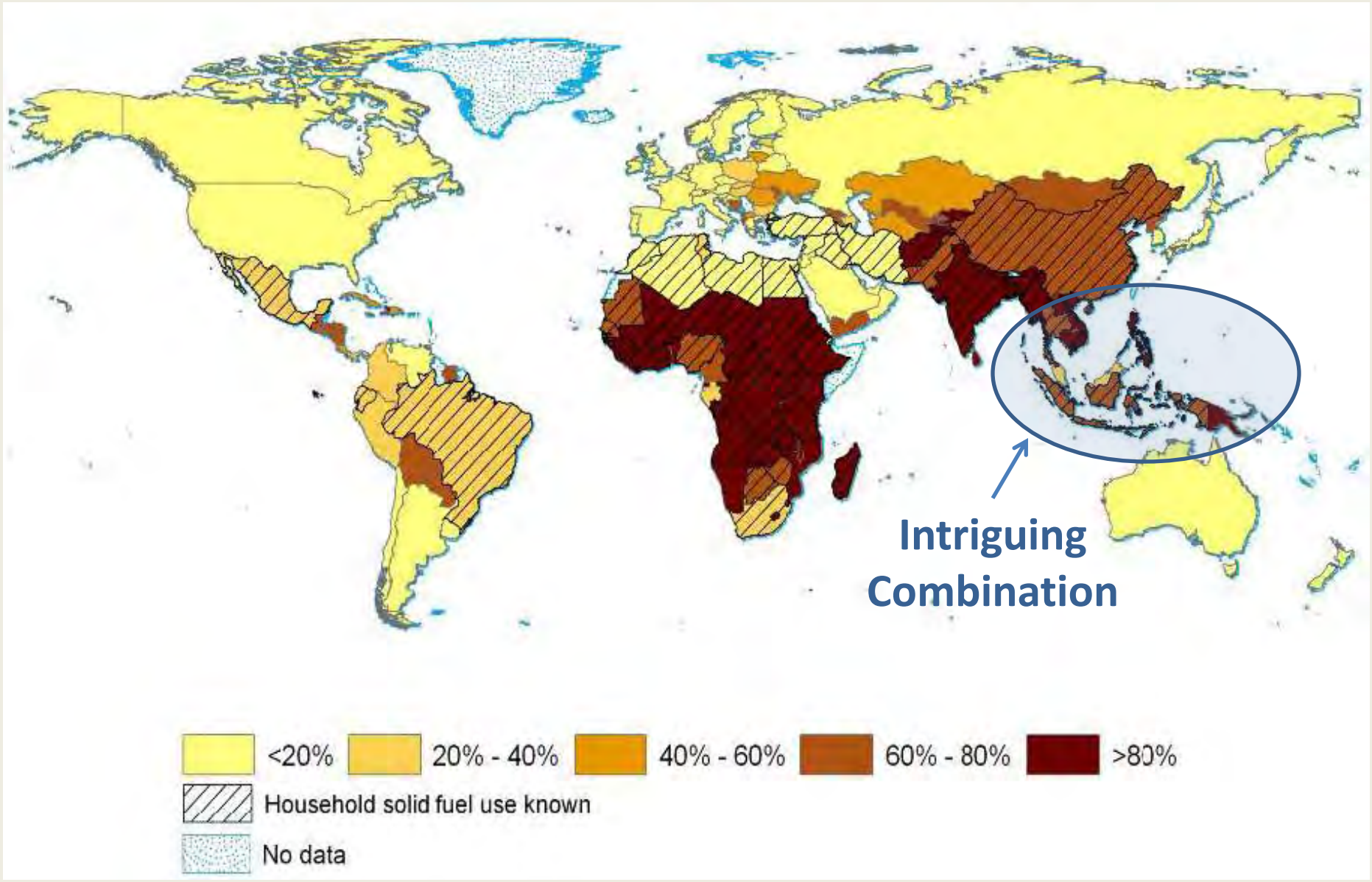
Session Introduction

Steven Garrett

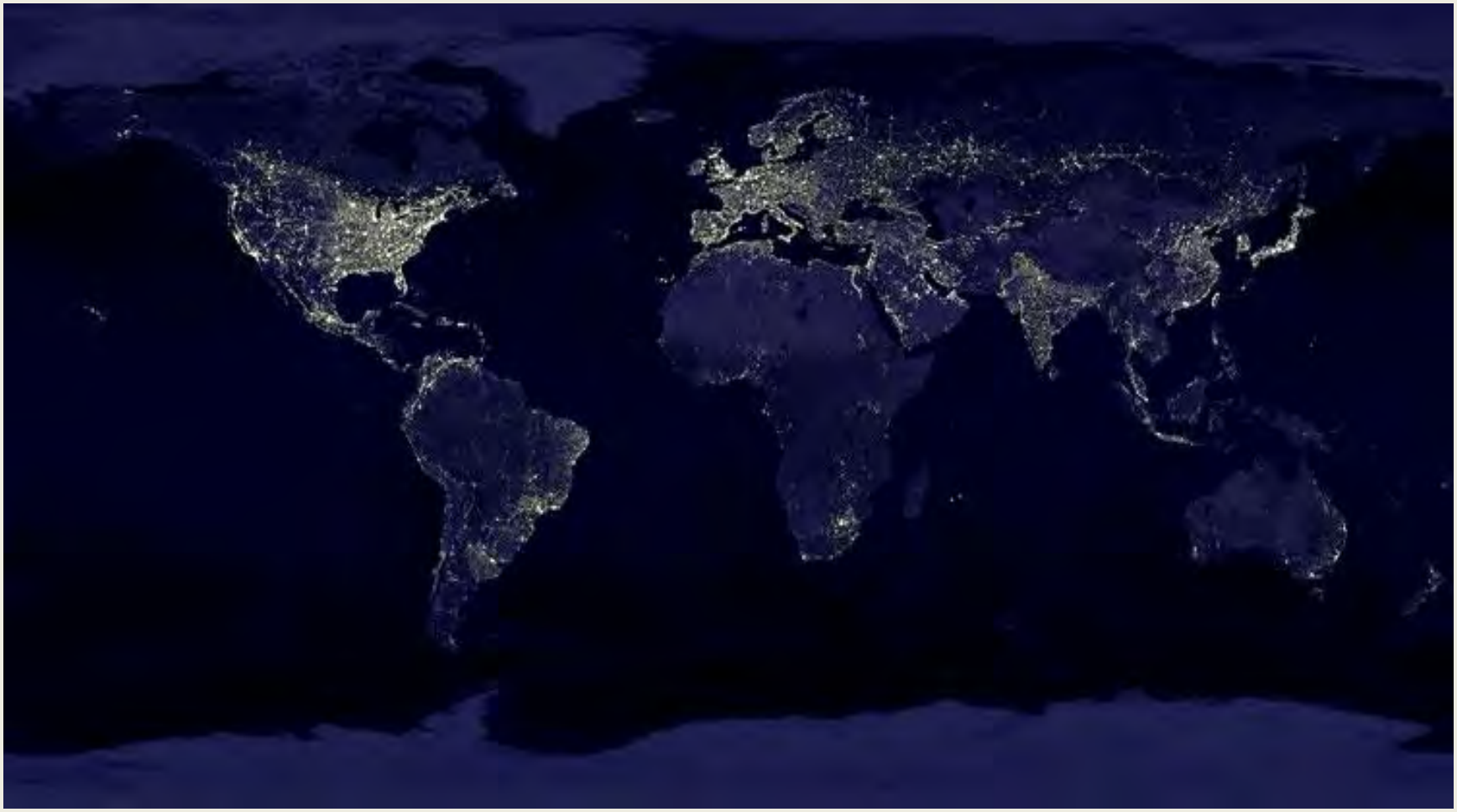
US State Department - Jefferson Science Fellow

Penn State - United Technologies Corporation Professor of Acoustics

National Household Solid Fuel Use in 2000



The Photons of Modernity



Technology is IMPORTANT

"If user demand were the sole driver of innovation, the biomass cooking stove would be one of the most sophisticated devices in the world."

The Economist, 6 Dec 2008

Philips Woodstove for India

Field Test of 50 Units in India

"Wall Wart" Charger

- **Fans improve performance**
  - Fuel flexibility (*e.g.,* rice husks)
  - Reduced cooking time
  - Power control (boil *vs.* simmer)
  - Much lower toxic pollutants
  - Much lower soot production
- **Fans require electricity**
  - Available in India and China
  - Scarce elsewhere

Rice Husks in the Philippines

Alex Belonio
Winner of 2008 Rolex Award

Chinese Hybrid Gasifier Stove
National Stove Contest Winner 2008

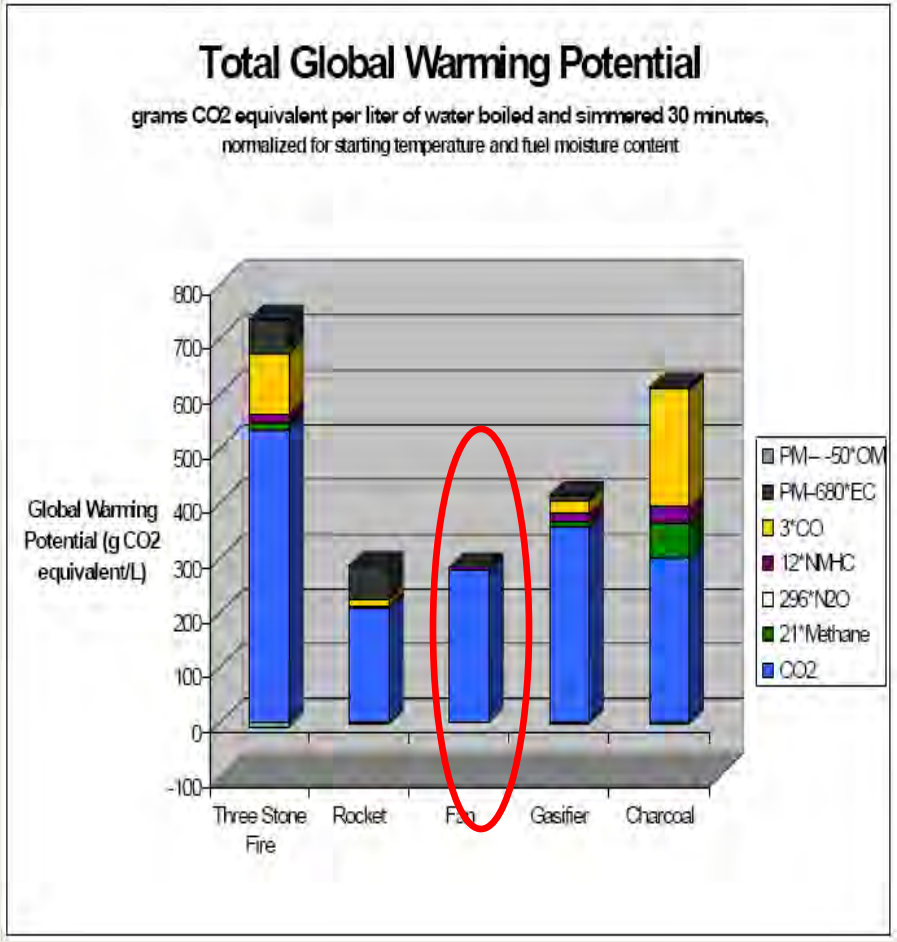
Efficiency 2x traditional stoves; Emissions 10-15x less:
Low health risk and essentially no greenhouse emissions

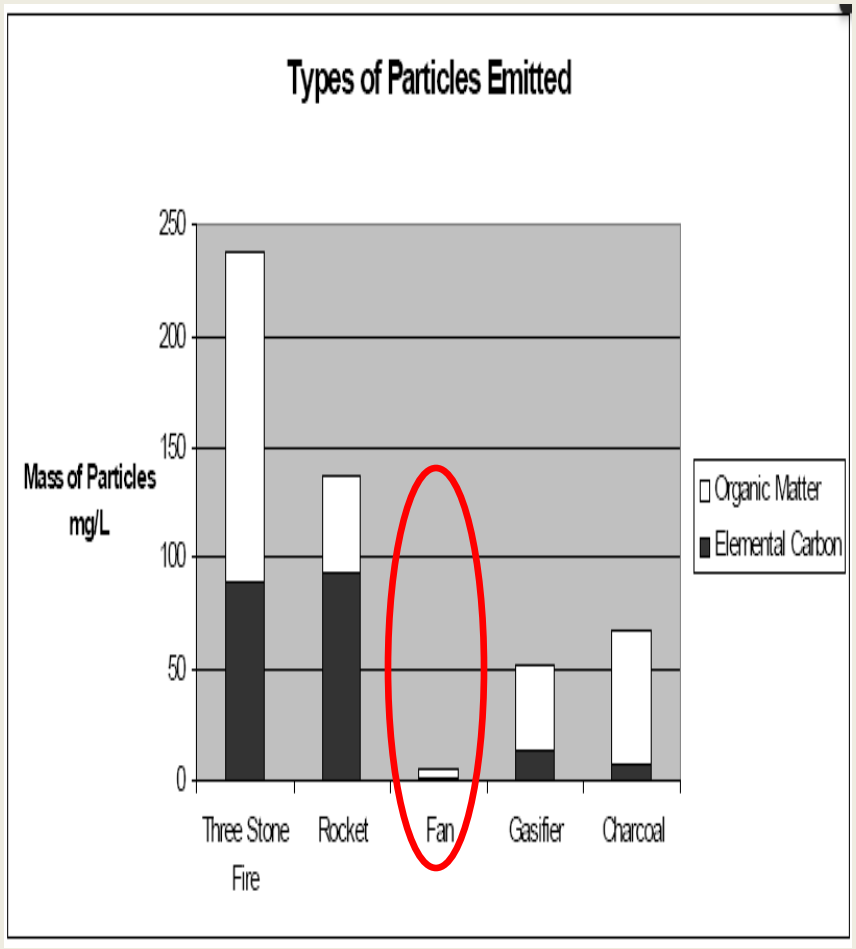
Compared to Coal Stove

17% to 41% fuel efficiency
0.12 to 0.02 CO/CO2
1.6 to 0.26 g PM/kg fuel

18 W blower

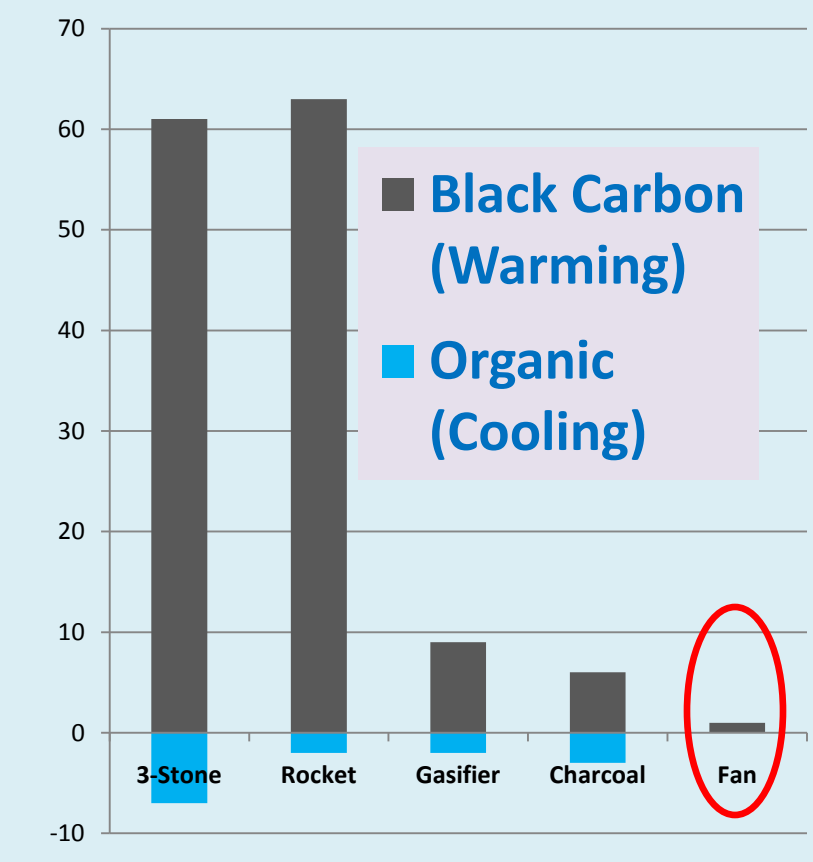
Fans Help: GWP and Particles

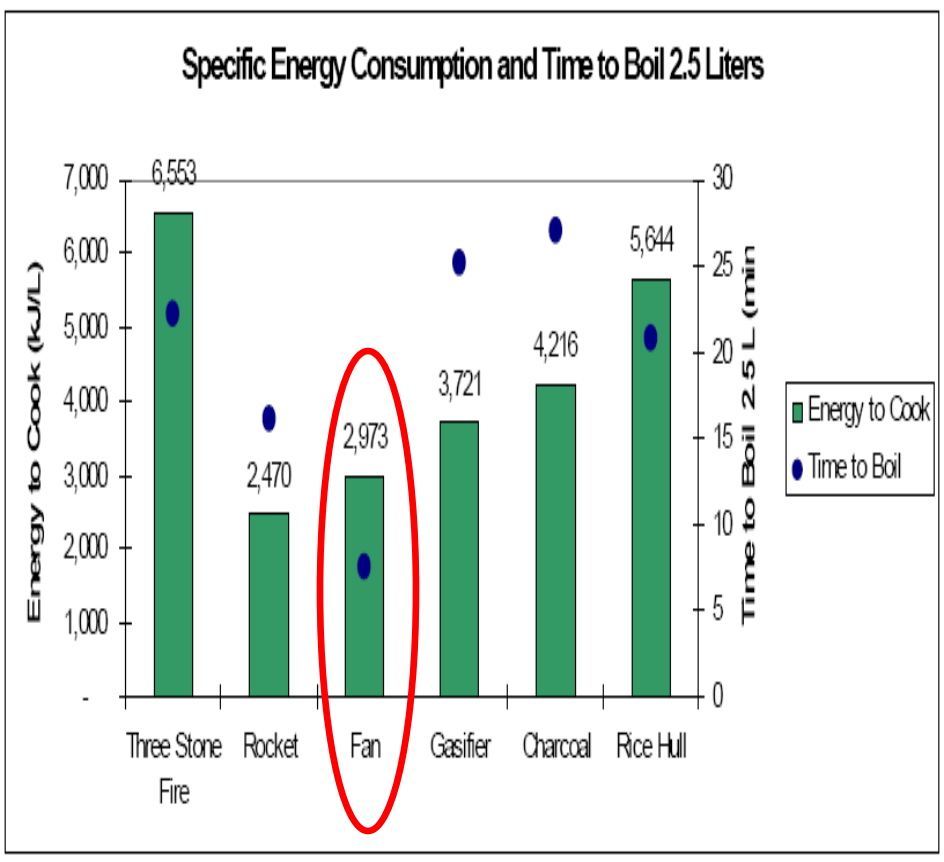




N. MacCarty, D. Ogle, D. Still, T. Bond, C. Roden and B. Willson, *Laboratory Comparison of the Global-Warming Potential of Six Categories of Biomass Cooking Stoves*, Tech. Report, 26-pages, Aprovecho Research Center, Advanced Studies in Appropriate Technology, Creswell, OR (Sept. 2007).

Black Carbon (Soot) and Cooking Time



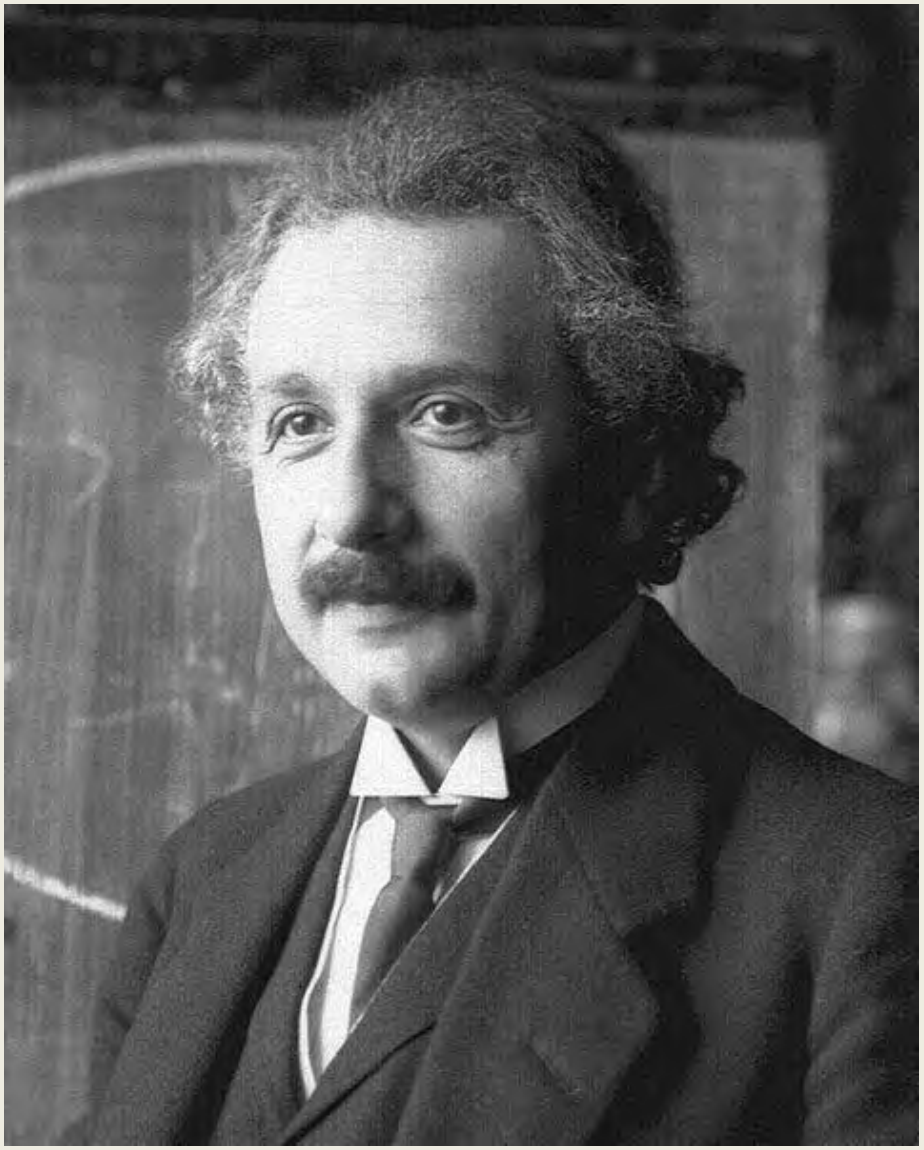


Nobody wants to spend more time doing food preparation!

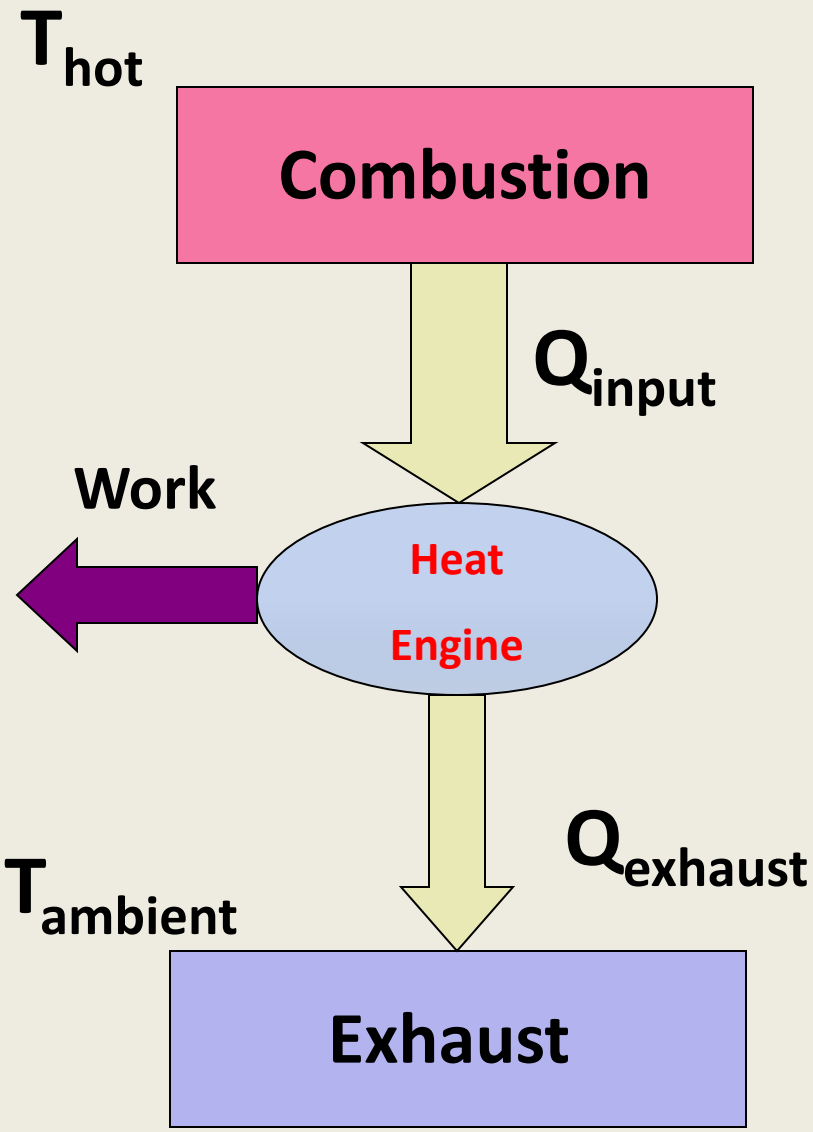
Thermodynamics

"It is the only physical theory of universal content that, within the framework of applicability of its basic concepts, ***will never be overthrown***."

Albert Einstein,
"Autobiographical Notes", 1949



Heat Is Not All Created Equal



- **The 1st Law**
  - Energy is conserved

$$Q_{exhaust} + \text{Work} = Q_{input}$$

- **The 2nd Law**
  - Entropy increases

$$\Delta S = \Delta Q/T$$

$$Efficiency = \frac{Work}{Q_{input}} \leq \frac{T_{hot} - T_{ambient}}{T_{hot}}$$

Session 4 – Utilizing Stove Heat for Co-Generation

1:10 – 1:30 Thermoelectric stove (B. Willson)
1:35 – 1:55 Thermoelectric stove (C. Lertsatitthanakorn)
2:00 – 2:20 Thermoelectric fan stove (J. Ceder)

2:25 – 2:40 Break

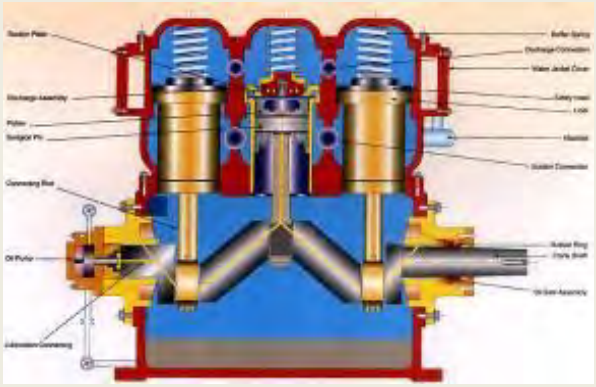
2:40 – 3:10 Thermoacoustic cogeneration applied to advanced cook stoves (S. Backhaus)
3:15 – 3:35 SCORE Project thermoacoustic co-generator (C. Lawn)
3:40 – 4:00 Steam electrical co-generation (C. do Canto Muniz)

4:05 – 5:45 Break-Out Sessions on Research Needs for Co-Generation
5:45 – 6:00 Co-Generation Break-Out Group Reports (B108)

6:10 – 7:45 Dinner

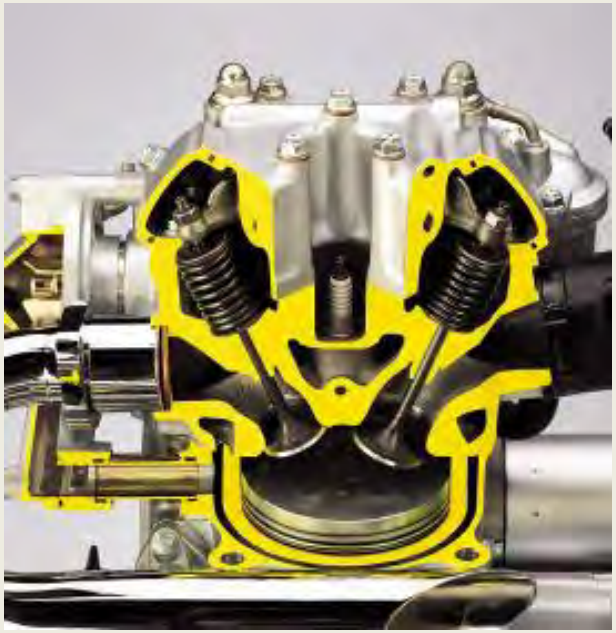
7:45 – 7:50 Presentation of Tomorrow's Schedule

Familiar Heat Engines

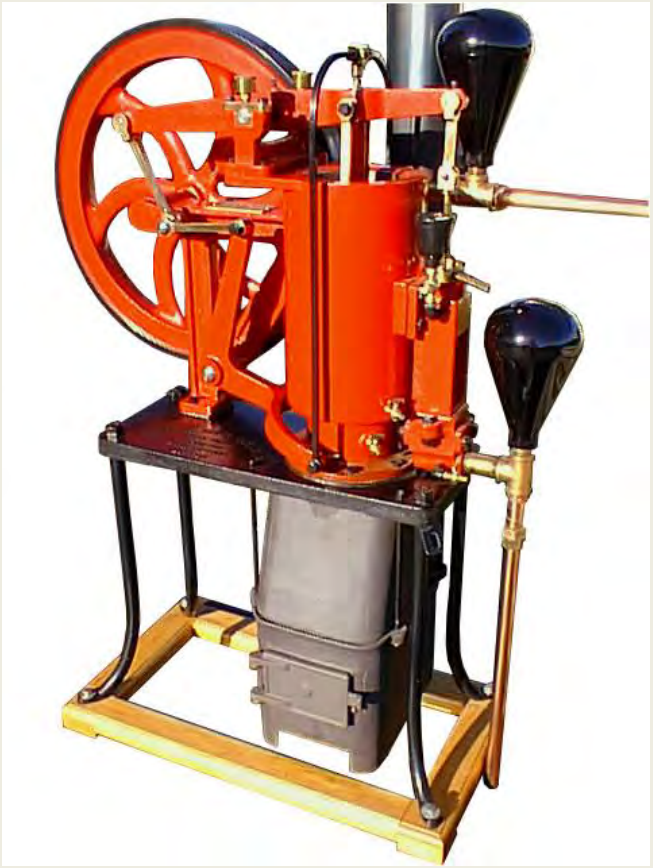


Pistons, Pushrods, Cams, Valves

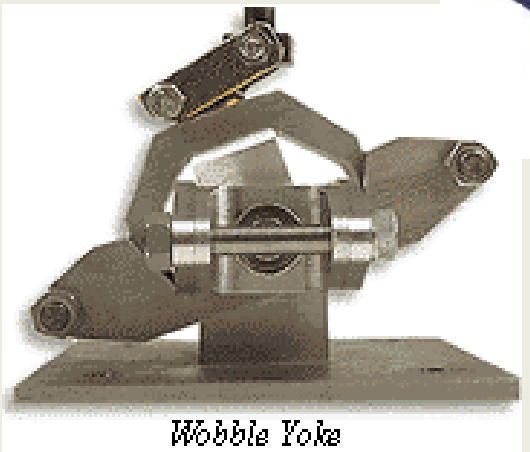
It's all about **phasing!**



Closed-Cycle Engine Technology



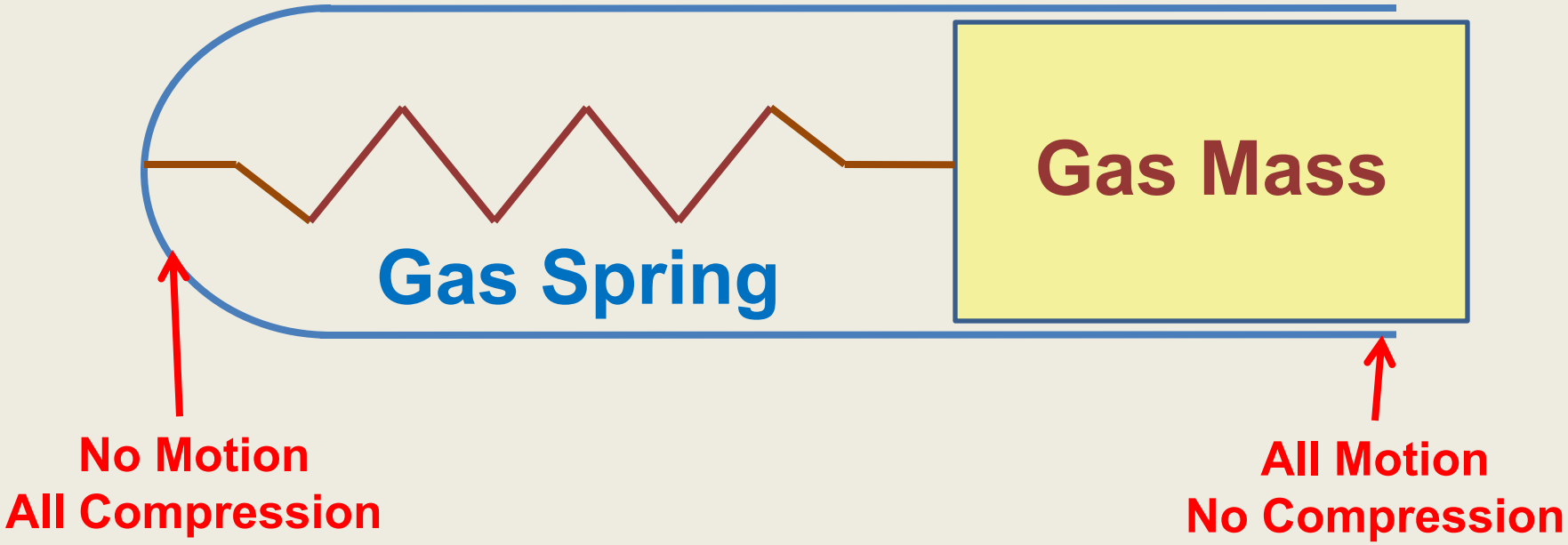
1895 Rider-Ericsson



2001 WhisperGen

Resonant Acoustical Phasing

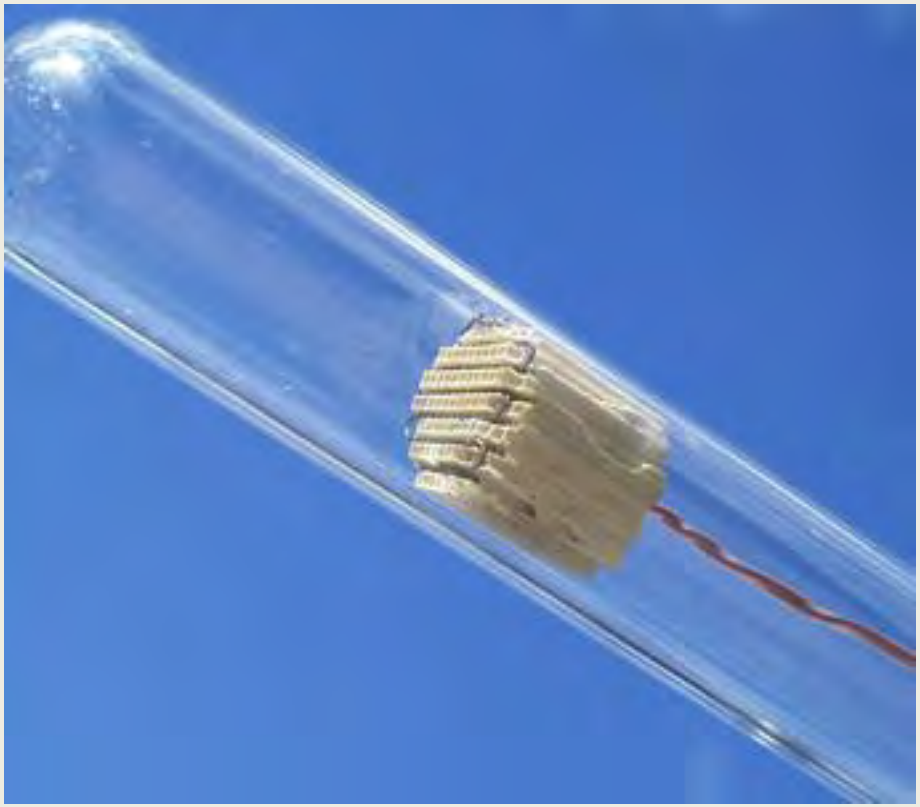
[*For a natural engine*]



Gas Compliance ↔ Gas Inertance ⇒ Harmonic Oscillations

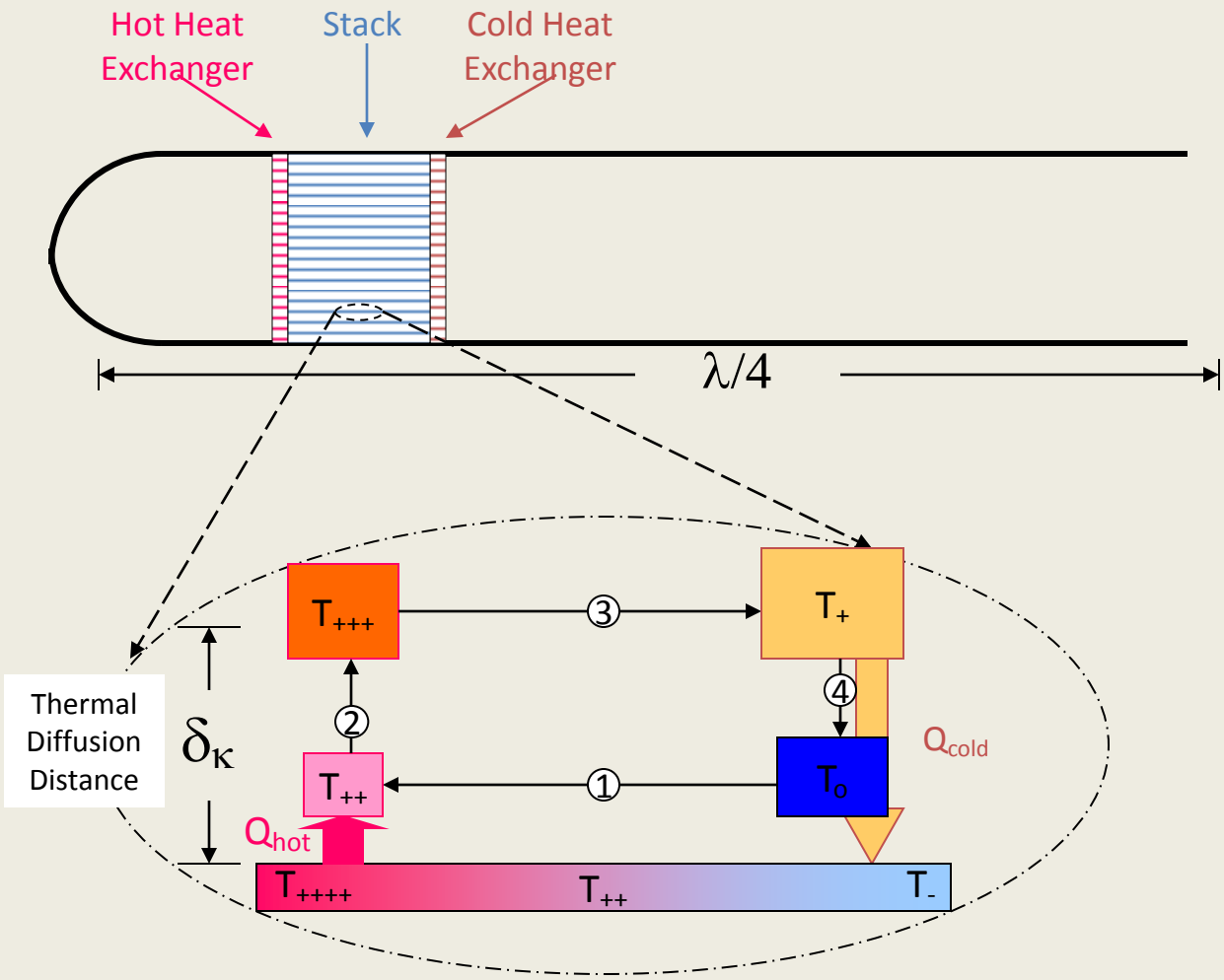
Thermoacoustic Engine Demonstration

- Heat and Heat Engines
  - Cook stoves are ***hot***
  - Heat can produce **work**
- Convert **work** to **electricity**
  - Generators
  - Linear alternators
- External combustion
  - Free piston Stirling
  - Steam (piston or turbine)
  - Thermoelectric
  - Thermoacoustic

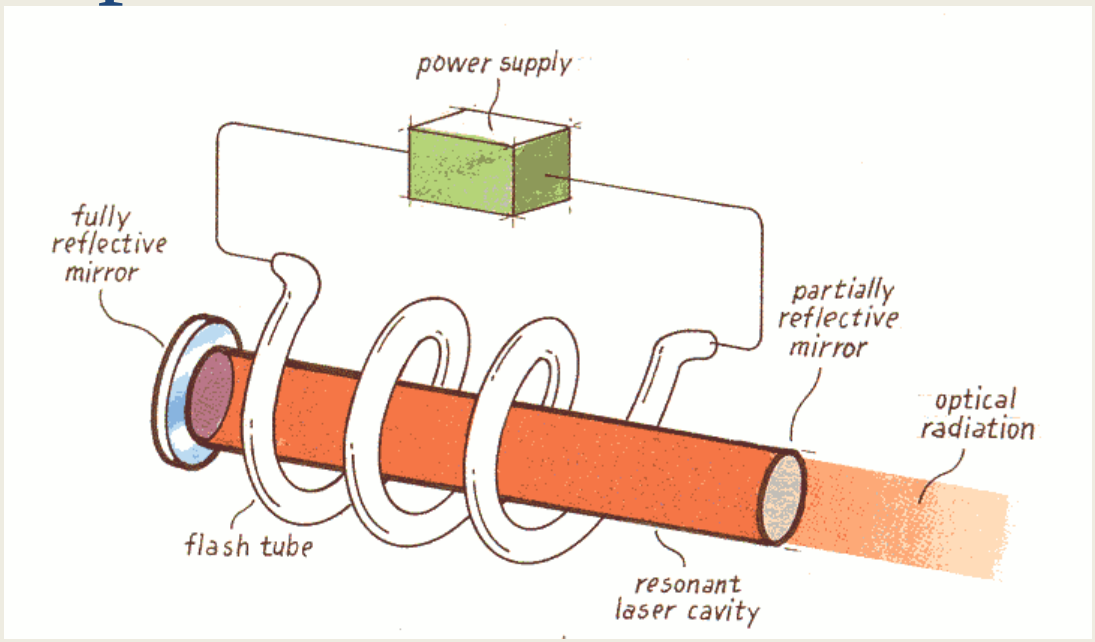


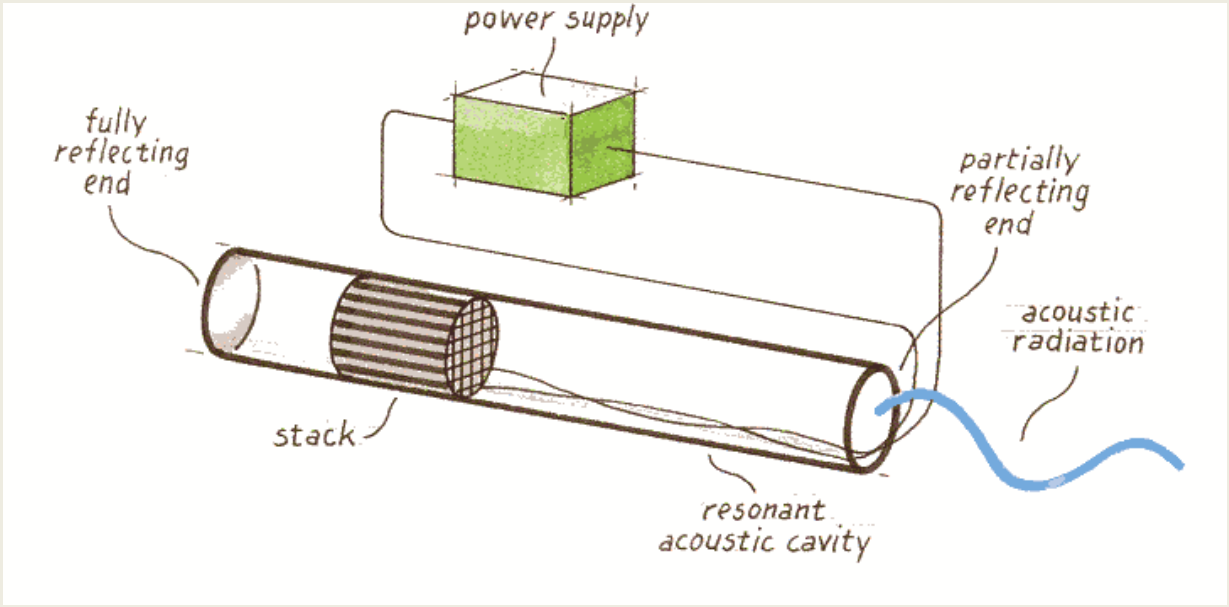
- Engine Requirements
  - **Robust**
  - **Inexpensive**
  - **Low maintenance**

Standing-Wave Prime Mover - Lagrangian Model



Optical Laser - Acoustical Laser





Next-Generation Cook Stove Workshop

Asian Institute of Technology: 16-20 Nov 2009

- How do you run a fan **without a power grid**?
  - Small scale heat engine technologists.
- How do you stimulate **adoption** of new stoves?
  - Corollary benefits of rural electrification.
- How do you make **millions of them**?
  - Indigenous manufacturing technologists.
- How do you **purchase** all those stoves?
  - Micro-finance and carbon credits experts.
- How do you **distribute** all those stoves?
  - Local merchants and entrepreneurs.
- Outputs?
  - **Design teams** for engines and monitoring.
  - Test, monitoring and **evaluation team**.